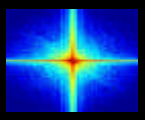
Spectral Processing of Point-sampled Geometry



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ETH Zürich

Outline

- Introduction
- Spectral processing pipeline
- Results
- Conclusions

Introduction

Model Acquisition
- Range scans
- Depth images
- ...

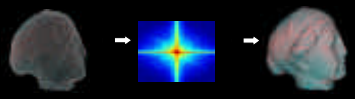
Point-based Geometry Processing

Spectral Methods

Point Rendering
- QSplat
- Surfels
- ...

Spectral Transform

- Extend Fourier transform to 2-manifold surfaces



⇨Spectral representation of point-based objects

⇨Powerful methods for digital geometry processing

Applications

- Spectral filtering:
  - Noise removal
  - Microstructure analysis
  - Enhancement
- Adaptive resampling:
  - Complexity reduction
  - Continuous LOD

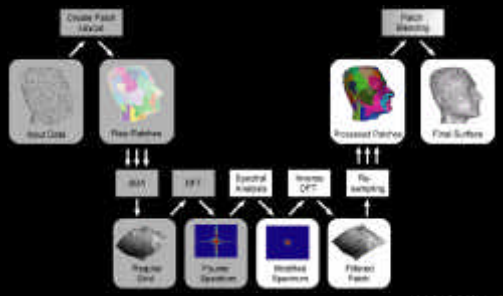
Fourier Transform

$$X_n = \sum_{k=1}^{N} x_k e^{-j2p\frac{nk}{N}}$$

- Benefits:
  - Sound concept of frequency
  - Extensive theory
  - Fast algorithms
- Limitations:
  - Euclidean domain, global parameterization
  - Regular sampling
  - Lack of local control

Spectral Processing Pipeline

Overview

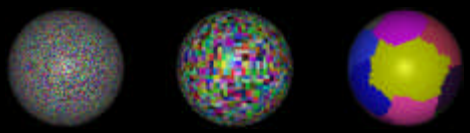


SIGGRAPH

Spectral Processing Pipeline

Patch Layout Generation

Clustering ⇨ Optimization



Samples ⇨ Clusters ⇨ Patches

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Spectral Processing Pipeline

Patch Merging Optimization

- Iterative, local optimization method
- Quality metric: $\Phi = \Phi_S \cdot \Phi_{NC} \cdot \Phi_B \cdot \Phi_{Reg}$
  - Φ_S ⇨ patch Size
  - Φ_{NC} ⇨ curvature
  - Φ_B ⇨ patch boundary
  - Φ_{Reg} ⇨ spring energy regularization

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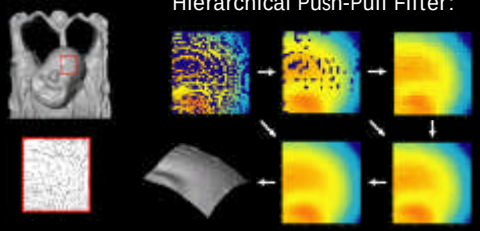
Spectral Processing Pipeline

Scattered Data Approximation

Hierarchical Push-Pull Filter:



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Spectral Processing Pipeline

Spectral Analysis

- 2D Discrete Fourier Transform (DFT)
  - ⇨ Direct manipulation of spectral coefficients
- Filtering as convolution:

$$F(x \otimes y) = F(x) \cdot F(y)$$

  - ⇨ Convolution: $O(N^2)$ ⇨ Multiplication: $O(N)$
- Inverse Fourier Transform
  - ⇨ Filtered patch surface

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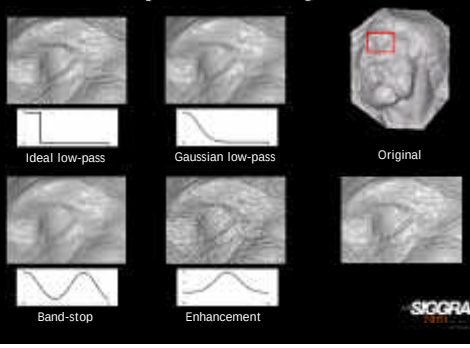
Spectral Processing Pipeline

Spectral Analysis



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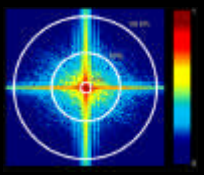
Spectral Processing Pipeline

Resampling

- Low-pass filtering
  - ⇨Band-limitation
- Regular Resampling
  - ⇨Optimal sampling rate (Sampling Theorem)
  - ⇨Error control (Parseval's Theorem)



Power Spectrum

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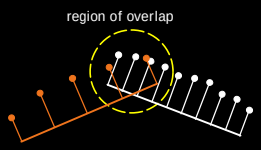
Spectral Processing Pipeline

Reconstruction

- Filtering can lead to discontinuities at patch boundaries
  - ⇨ Create patch overlap, blend adjacent patches

Sampling rates → Point positions → Normals



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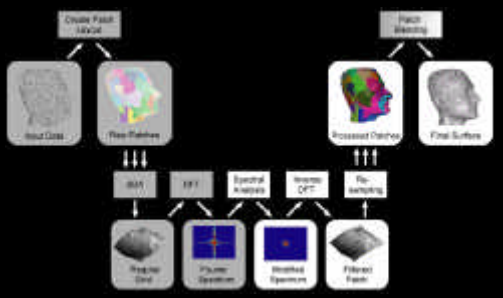
Spectral Processing Pipeline



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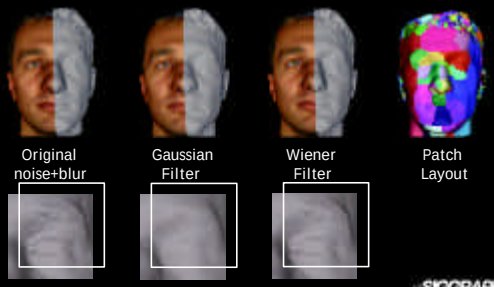
Results

Surface Restoration



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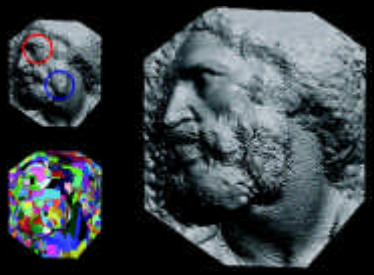
Results

Interactive Filtering



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Results

Adaptive Subsampling

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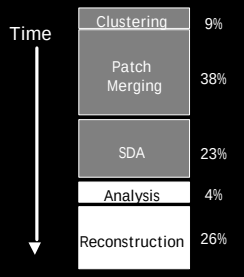
Timings



Timings

	 Head	 St. Matthew	 David
#points	460,800	3,382,866	4,128,614
#patches	256	595	2,966
Preprocess	10.9	117.2	128.3
Total	15.8	153.0	189.6

Summary

- Versatile spectral decomposition of point-based models
- Effective filtering
- Adaptive resampling
- Efficient processing of large point-sampled models

Future Work

- Compression
  - Scalar Representation + Spectral Compression
- Hierarchical Representation
  - Modeling and Animation
- Feature Detection & Extraction
  - Robust Computation of Laplacian

Acknowledgements

Our Thanks to:

Marc Levoy and the Stanford Digital Michelangelo Project, Szymon Rusinkiewicz, Bernd Gärtner